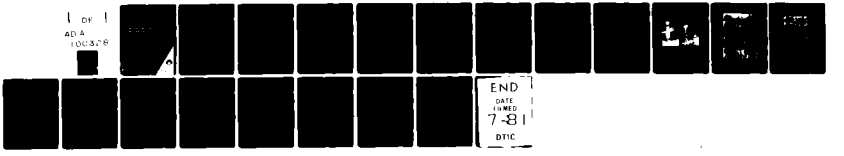
AD-A100 328 NAVAL OCEANOGRAPHIC OFFICE NSTL STATION MS F/G 8/1
BIOFOULING STUDIES IN THE BALTIC APPROACHES.(U)
MAR 81 J R DEPALMA
UNCLASSIFIED NOO-TR-262 NL



LEVEL II

TR-262

(12)

AD A098116

TECHNICAL REPORT

Biofouling studies in the Baltic Approaches

John R. DePalma

Approved for public release; distribution unlimited

MARCH 1981

PREPARED BY
COMMANDING OFFICER,
NAVAL OCEANOGRAPHIC OFFICE
NSTL STATION, BAY ST. LOUIS, MS 39522

PREPARED FOR
COMMANDER
NAVAL OCEANOGRAPHY COMMAND
NSTL STATION, BAY ST. LOUIS, MS 39529

FOREWORD

This report summarizes the results of a cooperative study of fouling communities in the approaches to the Baltic Sea carried out by the Royal Danish Navy, the Federal Republic of Germany Ministry of Defense, and the U.S. Navy during 1975 through 1977. This study is one of a series of regional studies of fouling communities to assess the local effects of fouling attachment on naval operations.

W. C. Palmer
Captain, U.S. Navy
Commanding Officer

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: NAVOCEANO-TR-262	2. GOVT ACCESSION NO.: AD-A100 328
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: BIOFOULING STUDIES IN THE BALTIC APPROACHES	5. TYPE OF REPORT & PERIOD COVERED: Final. 1975-1977
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): John R. DePalma	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Naval Oceanographic Office, NSTL Station, MS 39522	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Naval Oceanographic Office	12. REPORT DATE: [illegible] 81 13. NUMBER OF PAGES: 22
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*	15. SECURITY CLASS. *(of this report)*: UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

biofouling
marine borers
test panels
Danish Sounds

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

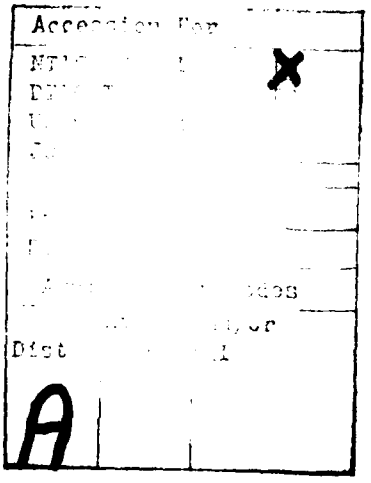
During 1975-1977, biofouling organisms were collected at 21 sampling stations located in a variety of depths and environments in the Danish Sounds. The collected data show that from an engineering point of view, marine fouling organisms will be a problem throughout the operation area, and at all depths. Marine borers, however, will be encountered only in the northern portion of the survey area.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

ACKNOWLEDGEMENT

Many people contributed to the success of the program. Commander Jesper Dineson of the Royal Danish Navy had overall responsibility for field work at the primary stations; Mr. Dunnie Tuck, Mr. John Bunce, Mr. Howard Huddell, and Mr. Craig Willett of the U.S. Naval Oceanographic Office (NAVOCEANO) placed and recovered test panels at the deep stations. Mr. Torben Rasmussen and Mr. Hans Peter Bok of the University of Copenhagen processed some of the test panels from the pilot phase of the program. Mr. Michael Neill of NAVOCEANO x-rayed the wooden test boards.



INTRODUCTION

Fouling organisms are known to affect the operating efficiency of underwater hardware and sensors. Thus, for planning purposes, it is important to know what kinds of fouling organisms will be encountered in operational areas, and if these organisms will be found in sufficient numbers to cause problems.

The scientific literature of the Danish Sounds region (sometimes referred to as the "Danish Straits") contains only one reference to fouling distribution with depth; a report on the epifauna of a German submarine net that protected the entrance to the Oresund during 1940-1945 (Brattstrom, 1946). To supplement Brattstrom's data, the Royal Danish Navy and the U.S. Navy undertook a cooperative study of the distribution and abundance of fouling species in the approaches to the Baltic Sea during 1975-1977.

This report is a summary of the results of this investigation.

METHODS

We wondered if low salinity water would limit the distribution and abundance of local fouling organisms. Brackish water from the Baltic Sea flows northward at the surface through the Danish Sounds, while North Sea water flows toward the Baltic along the bottom. The mean surface salinity in the southern ends of the sounds is about 10 parts per thousand (^{o}/oo). The salinity increases to 15 - 20 ^{o}/oo in the middle portion of the sounds, and to 22 - 25 ^{o}/oo at northern ends (Alhonen, 1966). Since the sounds are narrow and shallow, intensive vertical mixing takes place (Sverdrup et al., 1942).

To learn how this complex environment affects the local fouling populations we sampled at the twenty-one sites indicated in figure 1 and table I, using standard test panels as biofouling collectors. Standard biofouling test panels are made from 15 cm. by 30 cm. sections of wood and asbestos attached to one another like a sandwich and held in place with brass screws. The asbestos is for the attaching organisms; the wooden portion collects boring organisms.

Nine primary sampling sites were selected in the survey area, each approximately 0.2 nautical mile from shore (fig.1, #1 thru #9). At each of these stations, twelve test panels were attached about 8 meters below the surface, as shown in figure 2. We removed one test panel from each station each month for twelve months.

We also sampled at twelve secondary stations (fig.1, #I thru #XII), to assess the effects of depth and distance from shore on fouling rates. At each of these offshore stations we exposed a single test panel close to the bottom for approximately one year. These test panels were attached to current meter support platforms placed on the bottom in water depths of 15 to 29 meters (table II). Test panels at both the primary and the secondary sampling stations were deployed and recovered by divers.

After recovery the test panels were preserved in alcohol and shipped to the Naval Oceanographic Office for analysis. Laboratory analysis consisted of identifying the various species, determining their relative abundance on each of the test panels, and measuring the hardshelled forms. The fouling organisms were then removed from the asbestos surfaces, air-dried, and weighed for assessment of biofouling productivity.

Wooden test panels were x-rayed to obtain a count of the marine borers, then opened to collect and identify species.

Underwater photographs of the test panel arrays were taken to determine the vertical distribution of fouling organisms of floats and mooring lines.

DISTRIBUTION AND ABUNDANCE OF FOULING ORGANISMS

The organisms that attached to floats, mooring lines, and test panels usually arranged themselves into two distinct assemblages - one near the surface (to about 11 meters below mean low water) and another near the bottom. The near-surface assemblage was dominated by the mussel Mytilus edulis; the near-bottom assemblage was dominated by the barnacles Balanus crenatus and Balanus improvisus.

Mytilus edulis attach to a substrate with the help of tough, proteinaceous threads called the "byssus". Where there are a superabundance of Mytilus, they attach to one another with these byssal threads, forming tightly bound clusters. The clusters near the top of our test panel mooring lines (fig.2) sometimes grew to 15 centimeters in diameter during the growing season (May through October).

Barnacles, which cement themselves directly to the substrate, attain an adult height of only about 1.5 centimeters. They seldom accumulated to a thickness of more than 2.5 centimeters on any of the test surfaces.

There were wide variations in total biomass at both the primary and the secondary sampling stations (table II), even though the dominants were regionally well-distributed (table III). This "patchiness" is not unusual in complex coastal environments where fouling communities must contend with transient physical and biological factors that affect settlement and growth (pollution, water movement, competition, etc.).

Our total biomass data (table II) showed no north-to-south trend. The only real trend was depth-related; the shallow stations were, on average, more than twice as productive as the deep stations.

MARINE BORER DISTRIBUTION AND ABUNDANCE

Teredo navalis and Limnoria lignorum were the only marine borer species found in wooden test panels, and these only at stations north of 55° 22'N latitude. The apparent salinity limitation on the local distribution of these two borers is in accordance with observations by Somme (1940), who reported that Limnoria lignorum occurs along the Danish coast only as far south as

Kjels Nor, where the yearly average salinity is 14.3 °/oo; and by Miller (1926), who found that Teredo navalis remains active at salinities no lower than about 9 °/oo.

Of the two borers, Teredo navalis is the more destructive of marine materials; it is known to attack cordage, plastics, rubber, and gutta percha (Snoke, 1957; Bultman & Southwell, 1971). Teredo bore tunnels by using an upward and downward movement of their denticulated shells, and are most active when the water temperature is between 15°C and 20°C (Perkins, 1974). At stations 5, 6, 7, 8, I, VIII, and XI, Teredo navalis tunneled into the wooden panels at the rate of about two centimeters per month during the summer months.

Limnoria lignorum also degrades cordage and the gutta percha of submarine cables (Snoke, 1957) but is not known to attack either plastics or rubber. It can, however, consume it's weight in wood in approximately nine days (U.S.N. BuYards & Docks, 1965).

Unlike the molluscan borers, Limnoria tunnel by chewing with their mandibles. In wood they make tunnels just beneath the surface, with small holes cut in the roof of the tunnel at regular intervals to assist in aeration. These holes are distinctive and make Limnoria damage to wood easily identificable (fig.4). In Danish waters, Limnoria are active throughout the year.

Limnoria lignorum were found only occasionally in our test boards. This animal is a poor swimmer and does not migrate very far from it's shoreline broodsites.

RECOMMENDED PROTECTIVE MEASURES

It is now readily apparent that there will be sufficient numbers and kinds of fouling organisms throughout the survey area to affect the hydrodynamics of unprotected moored objects in the upper 11 meters, and the sensitivity of unprotected instruments at all depths.

Toxic paints have long been the traditional method of protecting surfaces from fouling attachment. Table IV lists the advantages and disadvantages of the general types of antifouling paints. Cuprous oxide is still the most effective and most widely used toxicant; a properly applied coating will usually provide good service for eighteen months or more. Organometallic toxicants are new and have appeal because of their noncorrosive qualities but their effective life in a paint matrix is somewhat shorter than for cuprous oxide.

In addition to toxic paints there are a number of other techniques that have been investigated for fouling control. These are reviewed in table V. Of these methods, however, only the rubberized fabric coatings impregnated with tributyltin compounds have proven to be practical or long-lasting for most Navy applications.

Full-cell pressure treatment with whole creosote is the recommended wood preservative in waters inhabited by Teredo navalis and Limnoria lignorum.

REFERENCES

Alhonen, P. 1966. Baltic Sea. In: The encyclopedia of oceanography, p.88. Edited by R.W. Fairbridge. Reinhold Publishing Company, New York, N.Y.

Benson, P.H., D.L. Brining, and D.W. Perrin, 1973. Marine fouling and it's prevention. Mar. Technol 10(1):30-38.

Bultman, J.D., and C.R. Southwell, 1971. An investigation of marine borer resistance of polymeric materials. NRL Report 7343. Naval Research Laboratory, Washington D.C.

Brattstrom, H., 1946. On the epifauna of an antisubmarine net in the northern part of the Sound. Kungl. Gysiografiska Sallskapers I Lind Forhandlingar Bd 16. Nr 6:38-44.

Miller, R.C. 1926. Ecological relations of marine wood boring organisms in San Francisco Bay. Ecology 7(3):247-254.

Perkins, E.J. 1974. The biology of estuaries and coastal waters. Academic Press, New York, N.Y., p.380.

Somme, O.M. 1940. A study of the life history of the gribble Limnoria lignorum in Norway. Nytt. Mag. f. Naturvidenskapene 81:145-205.

Snoke, L.R. 1957. Resistance of organic materials and cable structures to marine biological attack. The Bell System Technical Journal 36(5):1095-1127.

Sverdrup, H., M. Johnson, & R. Fleming, 1942. The Oceans, p.657. Prentice Hall, Inc., Englewood Cliffs, N.J.

U.S. Navy Bureau of Yards and Docks, 1965. Marine Biology Operational Handbook. NAVDOCKS M) 311. Department of the Navy, Washington D.C., p.31.

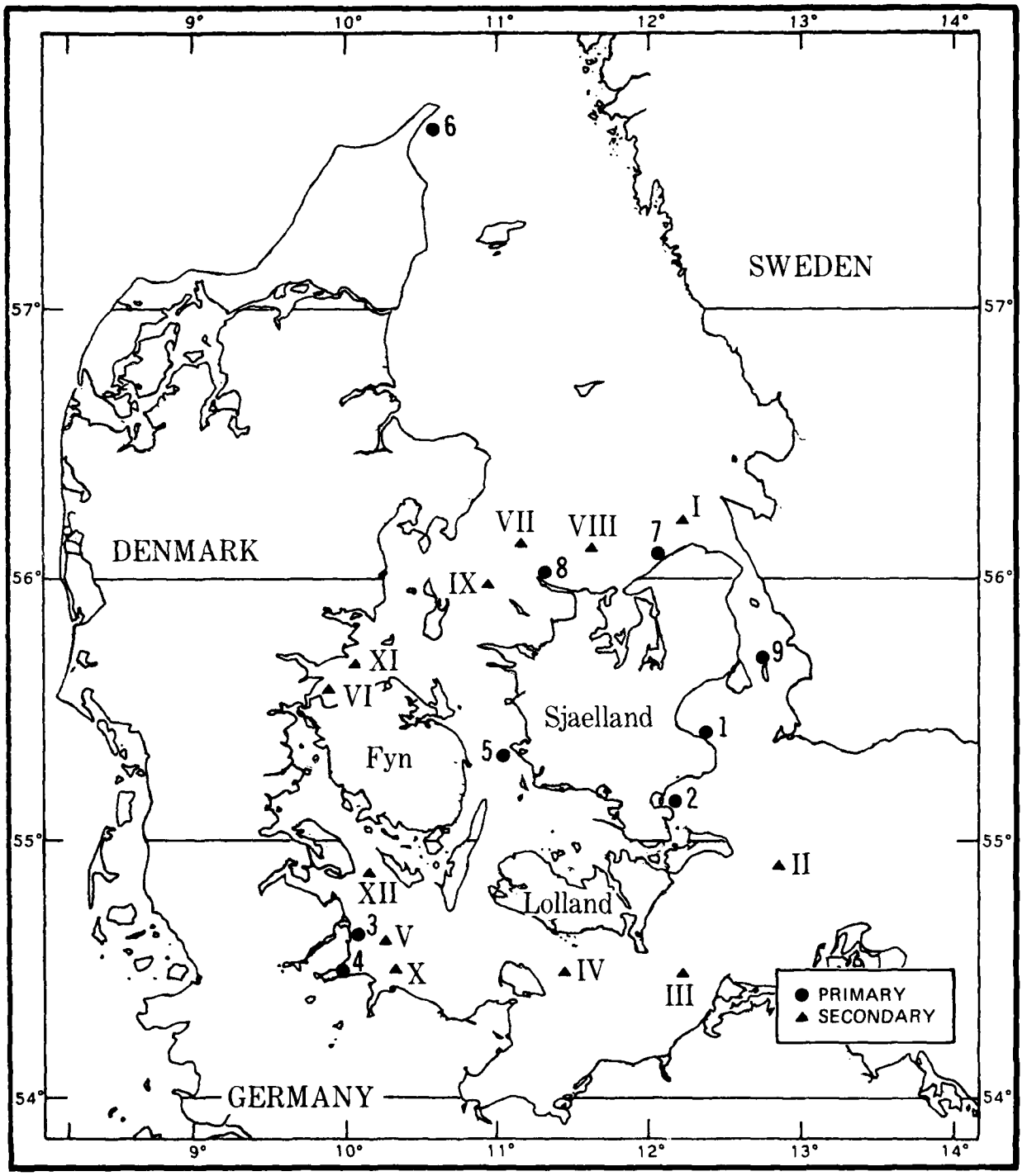


Figure 1. Biofouling stations

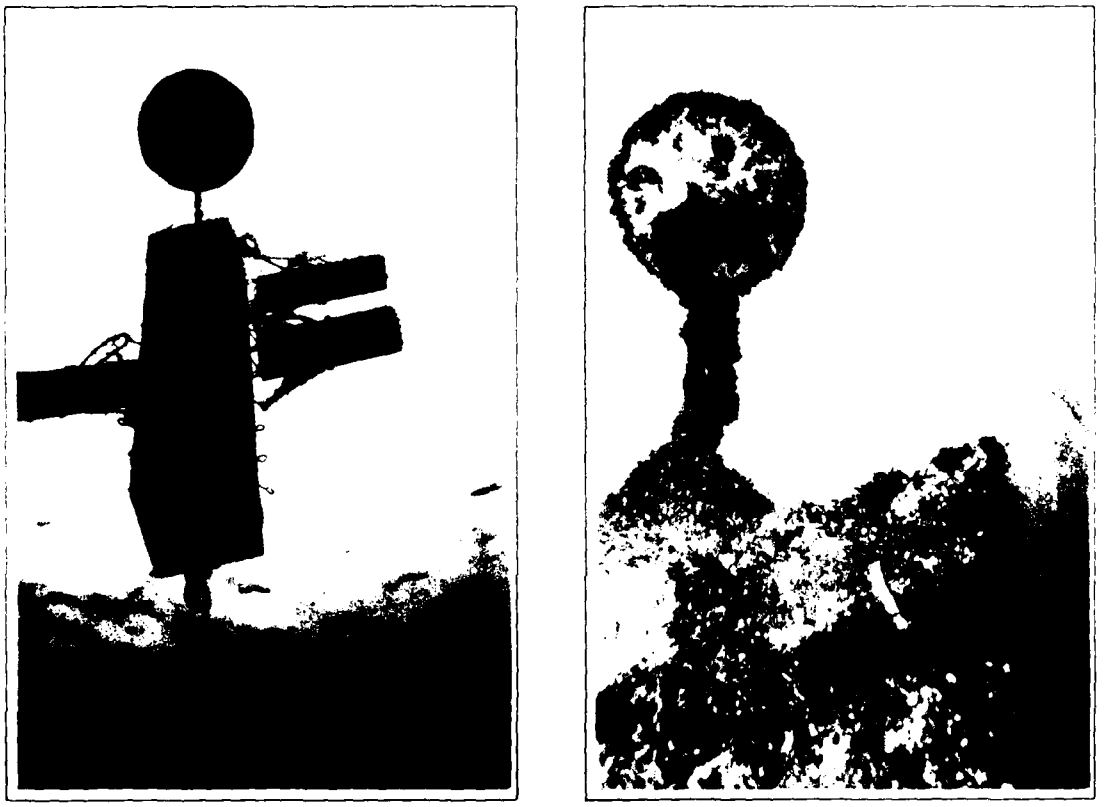


Figure 2. The method of exposing marine fouling test panels at primary sampling stations. The photo on the left shows relatively unfouled test panels and flotation gear at station 9 after a winter exposure (Sept -Mar). The photo on the right shows a more severely fouled array of panels at station 7 after a summer exposure (Mar -Sept).

Figure 3. Radiograph of a wooden test panel. The worm-like shapes are tunnels made by Teredo navalis after 6 months of exposure at station 7.

Figure 4. Wood damage by Limnoria. The photograph shows a characteristic pattern of aeration holes in the roofs of Limnoria tunnels.

Station	Coordinates · latitude(N)	longitude(E)	Sampling period
1	55° 24' 8"	12° 18' 8"	18 Feb.'76-18 Feb.'77
2	55° 10' 42"	12° 08' 6"	17 Feb.'76-19 Apr.'77
3	54° 36'	10° 4.5'	31 Mar.'76-4 Apr.'77
4	54° 28'	9° 55.8'	27 Feb.'76-7 Mar.'77
5	55° 22' 56"	11° 06' 12"	25 Feb.'76-23 Feb.'77
6	57° 30' 30"	10° 24' 30"	2 Mar.'76-2 Sep.'77
7	56° 03' 40"	12° 01' 36"	11 Mar.'76-13 Mar.'77
8	56° 00' 48"	11° 18' 00"	12 Mar.'76-10 Mar.'77
9	55° 43' 12"	12° 40' 18"	29 Mar.'76-13 Jan.'77
I	56° 14.6'	12° 14.8'	12 Sep.'75-20 Oct.'76
II	55° 49.5'	12° 42.2'	12 Sep.'75-30 Oct.'76
III	54° 33'	12° 17.2'	11 Sep.'75-15 Oct.'76
IV	54° 30.9'	11° 25'	10 Sep.'75-5 Oct.'76
V	54° 35.5'	10° 11.6'	10 Sep.'75-6 Oct.'76
VI	55° 35.1'	9° 50.9'	12 Oct.'76-14 Sep.'77
VII	56° 09.6'	11° 04.8'	16 Oct.'76-17 Sep.'77
VIII	56° 09.5'	11° 34.5'	16 Oct.'76-17 Sep.'77
IX	55° 57.5'	10° 59.3'	13 Oct.'76-17 Sep.'77
X	54° 30'	10° 18.7'	11 Oct.'76-13 Sep.'77
XI	55° 40.1'	10° 09.8'	12 Oct.'76-19 Sep.'77
XII	54° 54.6'	10° 09.5'	11 Oct.'76-21 Sep.'77

Table I - Sampling station coordinates and sampling periods.

Station number	Water depth (m)	Sample depth (m)	Distance from shore (nmi)	Dry weight production (gms/m^2/yr)
1	10	8	0.2	4,050
2	15	8	0.2	1,350
3	17	8	0.2	22,297
4	24	8	0.2	2,565
5	10	8	0.2	10,485
6	11	8	0.2	12,330
7	10	8	0.2	15,007
8	12	10	0.2	2,137
9	9	8	0.2	10,305
I	26	23	6.0	981
II	20	17	5.0	2,762
III	24	21	9.5	62
IV	27	24	4.5	1,807
V	22	19	6.0	2,492
VI	23	22	1.7	1,147
VII	22	21	11.4	624
VIII	20	19	11.2	1,964
IX	23	22	10.3	269
X	15	14	4.0	7,265
XI	21	20	4.0	8,001
XII	29	28	3.0	122

Table II - Sample depth and distance from shore vs. annual weight production, Danish Sounds survey area.

Organisms	Primary Stations									Secondary Stations											
	1	2	3	4	5	6	7	8	9	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Ulva lactuca						x															
Polysiphonia nigrescens									x												
Campanularia gelatinosa	xx	xx	x		xx	xx	xx	xx	xx		x	x			x		x	xx			
Obelia loveni	x	x	x	x	x			xx					x	x		x					
Tubularia larynx	x														x						
Metridium senile	x										x										
Conopeum seurati	xxx	xxx				x	x			x						x					
Electra crustulenta	xx					x		xx										x			
Bugula flabellata																		x			
Polydora ciliata				xx	xx	xx															
Pomatoceros triqueter						x	xx	x								x	x	x			
Balanus crenatus			xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx			xxx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xx
Balanus improvisus	xxx	xx			x	x	xx				xxx	xx									
Balanus balanus						x															
Limnoria lignorum						+	+								+						
Corophium robustum					x	x		x													
Mytilus edulis	xxx	xx	xxx	x	xxx	xx	xxx	xx	xxx												
Hiatella arctica					x	x		x													
Anomia simplex																	x				
Aeolis papillosa										x	x		x	x							
Teredo navalis	+				+	+	++	++									+	+			
Ciona intestinalis						x															

Legend: xxx = Fouling organism; dominant (>40% coverage of asbestos panel surface). xx = Fouling organism; common occurrence (2%-40% coverage). x = Fouling organism; rare occurrence (<1% coverage). ++ = Marine borer; found consistently in wooden panels. + = Marine borer; found only occasionally.

Table III - Distribution and abundance of fouling organisms in the Danish Sounds region.

PAINT TYPE	TOXIN	ADVANTAGES	DISADVANTAGES
Insoluble matrix (vinyls, epoxys, hot plastics)	Heavy metals	Proven effective. Hard durable surface	Heavy metals may present pollution problems. Requires high toxin loadings. Leaching rates variable.
	Organometallics	Highly toxic. Doesn't promote galvanic corrosion. Hard durable surface	Special handling required.
Soluble matrix (coal tar pitch or rosins)	Heavy metals	New toxic surface continuously exposed	Requires thick coating matrix. Erosion highly variable.

Table IV - Antifouling paints (adapted from Benson et al., 1973).

METHOD	PROBABLE MECHANISM	EFFECTIVENESS
Fresh water	Osmotic disruption of cells of organism.	Fouling reoccurs when marine habitat reentered; fails to remove dead organisms.
Constant substrate movement	Inhibits larval attachment.	Prevents zoofouling; inhibits algae at high speeds.
Ultrasonics	Repulsion; ruptures cellular structures.	Inconclusive; impractical application
Heat	Coagulates cellular protein.	Limited application; most effective above 210°F.
Air bubbles	Inhibits larval attachment.	Inconclusive; impractical application.
Peeling surfaces	Strippable plastic layers remove fouling.	Impractical; limited application.
Ultraviolet light	Disrupts cellular components.	Prevents all levels of fouling; limited application.
Colored surfaces	negative larval tropism.	Slight antifouling effects with green colors; temporary.
Hull cleaning	Mechanical removal.	Removes all fouling; application and longevity limited.
Elastomeric coverings	Organometallic toxin inhibits enzyme systems.	Prevents all levels of fouling; proven 16 year effectiveness.

Table V - Review of antifouling techniques other than paint (adapted from Benson et al., 1973).

METHOD	PROBABLE MECHANISM	EFFECTIVENESS
Electrical currents:		Limited to metallic structures
(1) alternating and pulsed currents	Secondary chemotoxic effects	Impractical application; high current density required.
(2) anodic dissolution of heavy metals	Inhibits enzyme systems, protein deterioration, degenerative effects.	Prevents zoofouling, inhibits algae; provides antifouling and anticorrosion protection; low current requirements.
(3) cathodic exfoliating surfaces	Exfoliating surfaces remove fouling.	Impractical; requires high current densities.
Chlorine, bulk addition	Oxidizes organic material.	Prevents all levels of fouling; application limited; safety hazards; highly corrosive.
Chlorine, electrochemically evolved	Oxidizes cellular components.	Prevents all levels of fouling; application limited.
Radioactive coatings	Radiation damage to cellular components.	Levels required to prevent fouling are impractical and hazardous.

Table V - Review of antifouling techniques other than paint (continued).

DISTRIBUTION LIST

CNR (Code 484)
CNO (OP-952F)
DTNSRDCDET - ANNAPOLIS
NAVOCEANSYSCENDET - KAILUA
NUSCDET - NEW LONDON (Code TA-13)
NRL (Code 8350)
COMNAVOCEANCOM
COMNAVFACENGCOM
NAVCOASTSYSCEN
NAVOCEANSYSCEN
NISC
FLEMINEWARTRACEN
NAVPGSCOL
CIVENGRLAB

DTIC 12 copies
USACE/NED - WALTHAM
USDAO - NEW YORK 09080 2 copies
USDAO - NEW YORK 09170 2 copies

HARVARD
TAMU
CLAPP
HBF - FORT PIERCE

INI&DP - ARGENTINA
MATRESLAB - AUSTRALIA
CUL - BELGIUM
ODEMA - BELGIUM
TIO/NBO - CHINA (PR)
SCSIO/AS - CHINA (PR)
IO/AS - CHINA (PR) 2 copies
IS/UC - DENMARK
HEMPLE - DENMARK
DIRTACTRA/RDNAVY - DENMARK 2 copies
IOF - EGYPT
IOF/HI - EGYPT
IOF/ASRT - EGYPT
FS/MU - EGYPT
HMDOCKYARD - ENGLAND
ACSI - ENGLAND
BIC - ENGLAND
PP/ML - ENGLAND
IMER - ENGLAND
SME - FRANCE
CNEXO - FRANCE
SOCREO - FRANCE
ERPROBUNGSTELLE - GERMANY (FR)
BWBF - GERMANY (FR)
BM - GERMANY (FR)
FMD - GERMANY (FR)

DISTRIBUTION LIST (con.)

IOFR - GREECE
MBS - INDIA
UK - INDIA
IAC/UG - ITALY
IL - ITALY 2 copies

NSM - JAPAN
DK - JAPAN
IMT - SOUTH AFRICA
DAH - SYRIA
OD/FS/SU - YEMEN AR
IB - YUGOSLAVIA


F
7